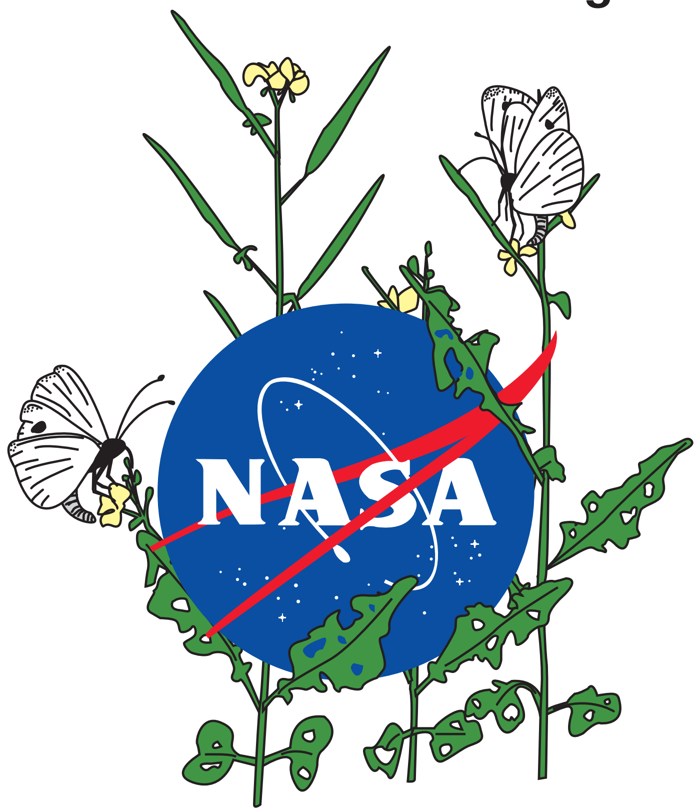
Brassicas and Butterflies Education Project

An Educator Guide for Working with Students in Grades 5 through 12



National Aeronautics and Space Administration

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Acknowledgement

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Space Life Science Research

Since the earliest days of modern space exploration, animals and plants have played a significant role in both the scientific understanding of the effects of the space environment on living things and in the development of technologies to support human space flight. Animals, serving as human models, preceded humans into space with the 1948 suborbital launch of a captured German V2 missile. The animal passenger was a rhesus monkey (*Macaca mulatta*) named Albert. By 1952, subsequent V2 launches established that non-human primates and white mice could survive the stresses of launch, brief periods of microgravity, and recovery. Five years later, a Russian dog survived a week in Earth orbit. The first humans began orbiting Earth in 1961. Ever since, animals and plants have accompanied humans into space and have been the subjects in a wide range of scientific experiments. Much of this research focused on how gravitational changes affect various components of living systems. For animal and plant investigations in orbit, gravity's effects become an experimental variable. Data from these experiments have provided valuable insights into a variety of diseases such as osteoporosis, immune system dysfunctions, and muscle atrophy.

As humans design longer space missions and missions far from Earth orbit, a more detailed understanding of space effects on living things will be needed. Since most space life science research to date has focused on specific organisms or specific animal and plant tissues, major questions relating to expanding human presence beyond Earth are left unanswered. A multi-year mission to Mars, for example, will require the continuous recycling of oxygen, water, and nutrients. Under current and anticipated space transport technology, delivering hundreds of tons of consumable supplies of these materials would be impractical.

On Earth, complex ecosystems consisting of living and nonliving components continually collect the Sun's energy and recycle oxygen, water, and nutrients. Earth's raw materials cycle over and over and nothing is wasted. Similar, though smaller and less complex systems for spacecraft and planetary habitats could be the answer to maintaining a viable long-term human presence in space.

Pieris rapae polinating *Brassica rapa*
Credit: Wisconsin Fast Plants ™

To establish closed ecosystems for long space flights and future Mars habitats, it will be necessary to expand the current space research focus on individual plant and animal species to include plant and animal interactions in the microgravity and low-gravity environments. The small size of spacecraft and environmentally controlled habitats on other worlds offers significant challenges to both science and technology. How can a relatively small isolated ecosystem function in a self-sustaining mode? How can these systems interact with astronauts? How can they be made to recycle sufficient quantities of oxygen and water and produce food?

Though not manifested for space flight, two species – *Brassica rapa* and *Pieris rapae* (the Chinese cabbage plant and the white cabbage butterfly) offer many opportunities for students to learn how to design and conduct space experiments with small ecosystems. *Pieris rapae* larvae feed on *Brassica rapa* or other members of the mustard family (cabbage, broccoli, cauliflower, collard, Brussels sprouts). Adult butterflies sip nectar from flowers and inadvertently assist in flower pollination. These species are inexpensive, easy to obtain, and easy to work with in the classroom at many grade levels. Once students master the skills for raising the butterflies through complete life cycles, they then are ready to conduct research with these organisms. They develop research ideas and construct and evaluate prototypes of studies or experiments that might be conducted on these species in the microgravity environment of Earth orbit and the low-gravity environments of the Moon and Mars.

Microgravity

A common misconception of space flight is that gravity goes away in Earth orbit and that is why astronauts and objects seem to float. Rather, it is the attraction of Earth's gravity that makes an orbit possible. Without gravity, a satellite would simply shoot out into deep space. Satellites, like the International Space Station, are launched above Earth's atmosphere and aimed in a path parallel to Earth's surface. Because of gravity, the path is bent into an arc as the satellite begins falling. However, if the forward velocity of the satellite is sufficient, the shape of the falling path matches the curvature of Earth's surface and the satellite literally travels around Earth indefinitely. Because it is falling, astronauts and objects inside the International Space Station do not feel gravity's effects. This creates the floating sensation and is called microgravity. (A much more detailed explanation of microgravity is available in the references listed in the resource section in this Educator Guide.)

On Earth, gravitational force is important in providing orientation and guidance to all forms of life including plants and animals. For example, plants orient themselves with gravity so that shoots grow up and roots grow down and water and nutrients are transported through the plants against the pull of gravity. Does gravity provide butterflies a means for orientation during egg laying, ambulation, pupation, emergence, flight, and resting? Establishing what is normal on Earth provides essential comparisons when research subjects are studied in microgravity.

How do plants grow in microgravity? What kinds of technology are necessary to promote plant growth and establish a butterfly life cycle in orbit? How might a butterfly's organ systems and behavior be affected by microgravity? How viable would a small ecosystem of brassicas and butterflies fare in microgravity?

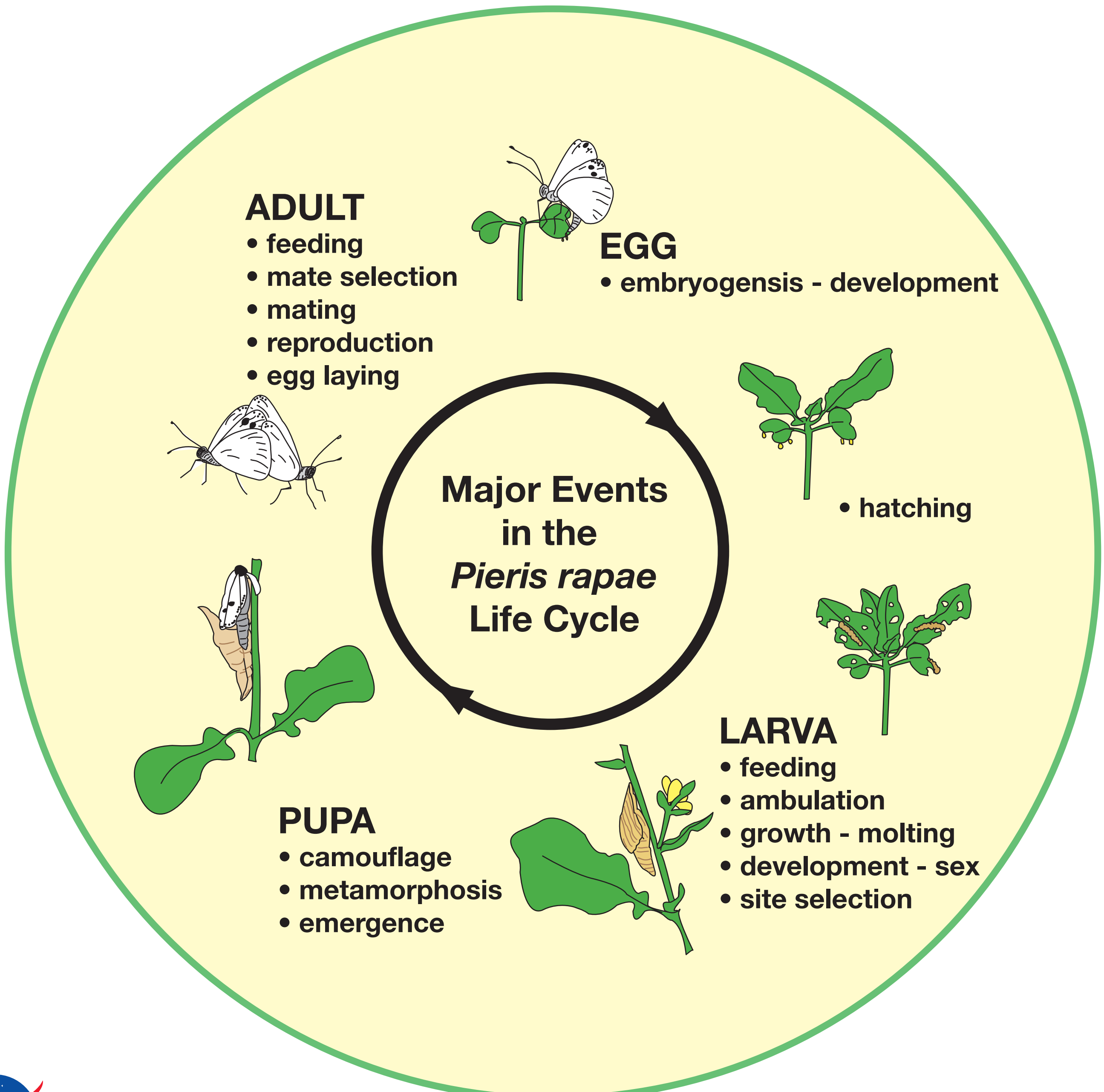
To further the research experience, students can also investigate the effects of hypergravity on the different life stages of the butterflies using various acceleration techniques such as makeshift centrifuges and rollercoaster rides. The inclusion of hypergravity studies with normal gravity and microgravity studies provides a gravity effects continuum for these creatures.

Model Organism

The white cabbage or *Pieris rapae (*or Brassica Butterfly) is an excellent model organism for classroom study. *Pieris rapae* can be reared from egg to adult in 35 to 45 days using simple low-cost habitats made from readily available recycled materials. The larvae feed on a wide range of brassica vegetables such as cabbage, broccoli, cauliflower, or Brussels sprouts that are always available in supermarkets or feed on Wisconsin Fast Plants ™ (*Brassica rapa*). The adults sip nectar from flowers or artificial nectar (sugar water and honey) from nectar feeders. The insect life cycle can be synchronized with the Fast Plant's life cycle for small ecosystem studies. *Pieris rapae* is easy to obtain because it exists in large numbers in most states and in many other countries around the world. From early spring to late fall students can observe them out-of-doors. The eggs may easily be collected from gardens or purchased through a biological supply company. (Please refer to the resource section of this educational guide for further information on obtaining plants and butterflies.)

How an insect changes from a tiny egg to an adult butterfly is a fascinating process. The butterfly life cycle investigation begins with eggs. From day one, students are making observations, predictions, collecting data, and asking questions about the life cycle. Once the eggs have hatched, the biology of this organism begins to unfold and students are challenged to understand not only the various stages of the life cycle, but also how it interacts with plants and other components of its environment. Each stage of the butterfly's development provides students with a wide range of opportunities to engage in real science.

Brassica and Butterfly Education Project
NASA's Fundamental Space Biology Outreach Program sponsors the Brassica and Butterfly Education Project developed by the Wisconsin Fast Plants ™ Program at the University of



Wisconsin at Madison. Through this project, teachers of all grade levels are trained in the techniques of raising *Pieris rapae* along with an assortment of brassica plants in their classrooms. In particular, the training focuses on the life stages of the butterflies and on scientific and technological questions related to the development of small ecosystems suitable for future research in space. Back in their classrooms, the participating teachers work with their students to master the skills necessary to raise the butterflies in Earth normal conditions. They then devise and test ground versions of experiments that could be flown in space.

Grade Level Appropriate Topics National Science Standards for Life Science	
Grades 5–8 • Structure and function in living systems • Reproduction and heredity • Regulation and behavior • Populations and ecosystems • Diversity and adaptations of organisms	**Grades 9–12** • The Cell • Biological evolution • Interdependence of organisms • Matter, energy, and organization in living systems • Behavior of organisms

Classroom Challenge - Brassica and Butterfly Project

1. Observe the life cycle of *Pieris rapae* and its relationship to *Brassica rapa* or other brassica vegetables.

2. Develop your own concepts and questions for a research study or formulate hypotheses for an experiment that could be conducted in orbit on the International Space Station. Collect materials and supplies and construct the apparatus needed for the Earth-based control for your study or experiment.

3. Conduct the Earth-based control study or experiment, collect and analyze data, and prepare a research paper summarizing your questions/hypotheses, procedures, and results. Speculate on how the results of your study or experiment would change in the microgravity environment of the International Space Station.

Potential Lines of Research on the Life Cycle of *Pieris rapae*

Life Stage	Aspect	Suggested Research Questions
Egg	Embryogenesis Development Hatching	What visual changes are evident? How long does it take for an egg to hatch?
Larvae	Feeding Choices Ambulation Growth – molting Development – sex Site selection for pupation	Do larvae prefer certain foods? How can you tell what a larva has been eating? How does a larva process food? How does a larva move? At what rate? How do you grow in a suit of armor? How does a larva molt? What is the heart rate of a larva? How does a larva breathe? How can you tell when a larva is getting ready to pupate? What is the orientation of a larva beginning to pupate? How does a larva attach itself to a surface before becoming a pupa?
Pupa	Camouflage Metamorphosis Emergence and wing expansion	How does a pupa adapt to its environment? What affects the color of the pupa? What visual changes are evident? How long does metamorphosis take? Can you sex a pupa? Why would you want to? How does the adult emerge? How much space does a butterfly need to pump up its wings?
Adult	Feeding Reproduction Egg laying	How does a butterfly feed? What attracts the butterfly to the flower? What are the feeding preferences of the butterfly? How and when do butterflies mate? How many times do butterflies mate? How can a male butterfly determine that a female has mated? How does a female butterfly detect a suitable plant host for egg laying? How does it lay its eggs? How many eggs can a female lay? How long can she lay eggs? Are there patterns in the timing of the egg laying?

Brassica and Butterfly Project - Classroom Activities

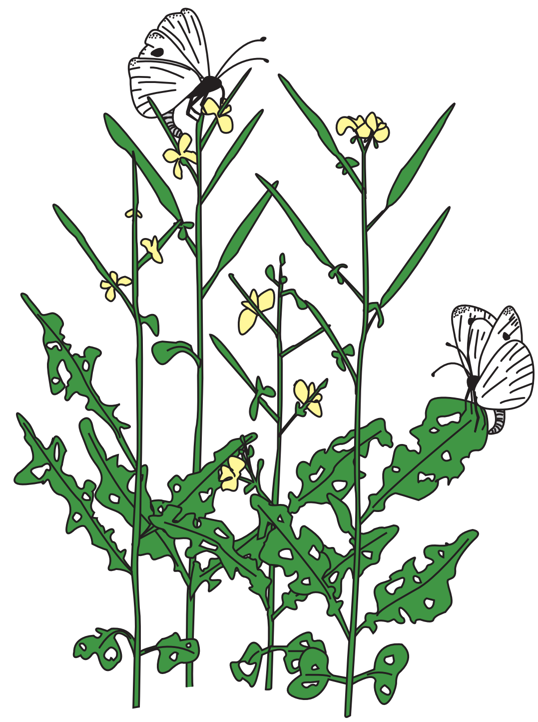
Raising Brassica Butterflies in the Classroom

The butterfly's life cycle begins with an egg, passes through 5 larval stages, transitions to a pupa and then, through metamorphosis, an adult butterfly. *Pieris rapae* develops from egg to adult in approximately 30 days. Butterflies mate, lay eggs, and, with proper nutrition and care, live for up to 3 weeks. Each stage of the butterfly's development provides students with opportunities for observations, ideas, analysis, experimentation, and creative communication. In part 1 of the activities, students will investigate the stages of the *Pieris rapae* life cycle and begin formulating research questions and hypotheses for Part 2 of the activities.

Prior to obtaining the butterflies through local collection or from a commercial supplier, suitable growing environments have to be created. In addition to the physical structure, food supplies will be needed. If you choose to use *Brassica rapa*, the seeds will have to be obtained from a commercial supplier. Refer to the sources section for supplier information.

Part 1: Getting Started on a Life Cycle

Tiny larvae emerging from eggs require tender, succulent brassica or radish leaf tissue. A "nursery" of various brassica seedlings, such as Fast Plants ™, turnips, and cabbage is ideal. The "nursery" Brassica Seed Mix should be planted 5 days prior to the scheduled delivery date of the butterfly eggs if using a commercial source or prior to collecting the eggs from gardens. Commercial butterfly eggs will arrive, via an overnight delivery service, on a piece of wax paper with approximately 30–50 eggs per egg strip. On average, each egg strip will provide 10–20 larvae.



Pieris rapae (white cabbage butterfly) feeding and laying eggs on *Brassica rappa* (Wisconsin Fast Plants ™)

Materials and Equipment:

- Light House
- 1 egg strip (30—50 eggs)
- Brassica Seed Mix
- 1 Butterfly Box*
- 1 Brassica Nursery*
- 1 Brassica Barn*
- 2 Film Can Sugar Feeders*
- 1 Film Can Ovipositron*

* Instructions for constructing these items begin on page 12.

Caring for *Pieris rapae*:

It is important to remember that to successfully raise any organism in the classroom through a life cycle, a suitable environment for that organism is needed. Environmental variations in temperature, humidity, light (intensity and duration), and nutrition may affect the success and the length of the butterfly life cycle in the classroom.

Temperature	Temperatures between 20–24°C are optimal.
Humidity	It appears that the greater the relative humidity, the better (up to 80%). No exact percentage has been quantified, nor is it easy to control in a classroom. To increase the humidity in a butterfly box, place a small dish of moist soil in the box. Keep it moist throughout the life cycle.
Light	The adult butterflies appear to prefer 16 hours of light and 8 hours of darkness inside the Butterfly Box.
Nutrition	As with all organisms, fresh food and water are essential.

Slowing Down the Cycle:
As with all cold-blooded insects and animals, the life cycle rate of *Pieris rapae* can be slowed down by reducing the temperature or accelerated with warmer temperatures. All stages of the life cycle can be manipulated by temperature. For example, if, on Friday, you find that all of the pupae are at the later stages of development and are going to emerge over a weekend, place them in a refrigerator at ~4°C and their developmental rate will slow enough so that they will not have emerged prior to Monday. On Monday, pull them out of the refrigerator, and they should resume a normal developmental rate.

Termination of Brassica Butterfly Life Cycle:
In many agricultural areas, *Pieris rapae* is considered to be a "pest" species. Rather than releasing the butterflies and larvae outside, the butterflies can be easily disposed of by placing them into a freezer overnight. They can then be discarded.

Disease Control:
Larval and pupal stages of *Pieris rapae* are very susceptible to various viral and bacterial insect pathogens.

Occasionally you may notice evidence of a bacterial or viral infection in a larva or chrysalis. The larva or chrysalis may look a little soft and then turn brown and "oozy." If this happens, you must institute rigorous sanitation or the infection can rapidly spread through the population.

If a larva looks soft or dull and develops black spots and then turns black or "oozy," remove the larva in such a way that it doesn't touch other larvae, plant leaves, or walls of the Brassica Barn. Use fresh, flat toothpicks and slide them under the caterpillar (don't poke or puncture it.) Then drop the caterpillar and toothpicks into a paper towel and dispose of it. Wash your hands thoroughly.

If a chrysalis looks soft or begins to turn uniformly black and looks dry, lift it with two flat toothpicks and dispose of it. If a chrysalis actually begins to ooze and secrete what one student described as "brown-green goo," more careful sanitation measures should be followed. Touch the pupa only with clean flat toothpicks or small pieces of paper toweling. Wipe any surface that they have touched with paper toweling and then wash your hands. It is recommended that you also move any other chrysalises to a clean container; wash down the "infected" container with a 5% bleach solution (1 cup of bleach/1 gallon of water) and finish by washing your hands.

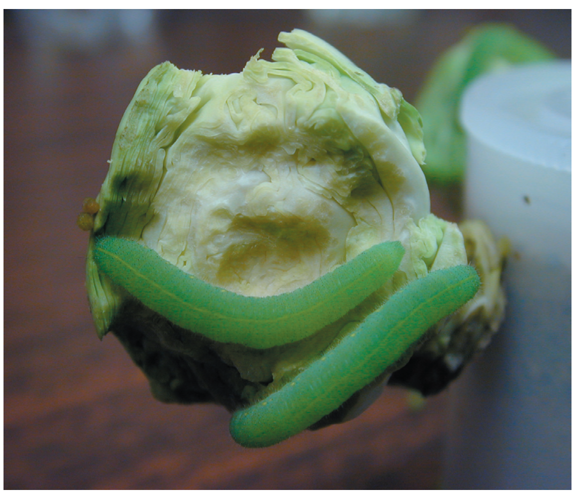
Part 2: Butterfly Rearing Timeline

The developmental timeline for the life cycle will vary depending on environmental conditions in your classroom. The following table summarizes events, maintenance, observations, and activities that occur during the rearing of *Pieris rapae*. More details on the specific stages of the life cycle will be found in the appendix.

DAY	EVENT	NOTES
–5 Days	Preliminary activities	Order butterfly eggs five days before the scheduled start of the activity. Plant nurseries for the arrival of the eggs. Build and assemble growing systems.
1	Start butterfly life cycle	Gently place the egg strip egg-side-down to cover one or more cotyledons on several *Brassica* seedlings in the Brassica Nursery. Important: Eggs are extremely fragile. Do not touch eggs! Check the water level in the reservoir.
2–10	Hatching, Larvae, Molting, Feeding, Silk Production, Defecation View stages with a hand lens or a magnifying TV camera.	Be patient with the eggs you receive in the mail. Generally the eggs will hatch within 2–4 days of arrival. It may take up to a week or more for the small larvae to be visible on the plant material. The tiny larvae crawl off the egg strips and feed on the Brassica seedlings. Larvae produce silk from a gland located below the jaws (mandibles). Larvae produce a track of silk glued on surfaces onto which they cling with their legs. Observe the characteristic swaying movement of the larva as it creates a strand of continuously overlapping silk. Larval excrement, called frass, looks watery under a microscope. It dries to fine, dark granules.
4–5	Check the water level in the reservoir.	*Pieris rapae* goes through 5 molts before becoming a pupa or chrysalis. Larvae seek a dry site, weave a fine carpet of silk, lie quietly for several hours, crack and crawl out of their exoskeleton, and finally pump up their new exoskeleton before it hardens.
7–8		Activity: Where's *Pieris* ?
10–11	Transfer larvae to Brassica Barn or Cabbage Café	When the larvae reach the L4 stage (See Appendix A.), transfer them to a Brassica Barn (10–15 larvae) or a Cabbage Café (60 larvae). Transfer the larvae very carefully. Do not poke through their soft bodies or squeeze them too hard.

DAY	EVENT	NOTES
10–18	Check daily that the food source is clean and free of frass. A clean flat toothpick makes a good frass remover. Replace the paper towel pad. Sanitation is extremely important at this stage in the life cycle.	Activities: Frass Forensics, Salad Bar
18–26	Metamorphosis	The transition of L5 larvae to pupae will occur in the Brassica Barn. Larvae are usually on the lid or sides of the container at this stage and are easily observed. The old, tightly condensed L5 exoskeleton with its head capsule appears at the extreme posterior of the pupa and often falls away from it, leaving the pupa belted to the carpet and attached at its posterior silk tuft by minute, Velcro-like hooks called a cremaster. Pupal external coloration may depend on light conditions, coloration of the surface on which pupation is occurring, the larval diet, or any combination thereof. Although the pupa appears to be quiescent or sleeping, metamorphosis is a highly active stage in which profound changes in the organism's form are taking place as the pupa remains attached to its silken carpet. After the Pg-2 stage, pupae can either be left attached to the silk mat and observed or they may be detached from their silk mat and secured with double-stick tape onto a piece of paper for viewing with a hand lens or dissecting microscope. Sexing the pupae: one (male) or two (female) dark wing spots appear in the center of the wings followed by a dark wing tip spot. If pupae are reaching the wing spot stage, emergence will take place shortly. Emergence can be delayed by refrigerating them at 2–4°C for a few days.

DAY	EVENT	NOTES
26–45	Emergence of adult butterflies, adult behavior Prepare Butterfly Boxes. Adult butterflies begin to emerge. Prepare sugar feeders. Prepare Ovipositrons. Conduct feeding choice experiments. Run egg laying experiments.	Prior to emergence, transfer pupa to an empty Brassica Barn for viewing. The pupa takes in air and accumulates fluids in the posterior region. The pupa appears somewhat swollen. Eyes become prominent and body hair becomes apparent under the anterior ridge between the two eyes. Adults emerge quite rapidly, sometimes in less than a minute. The exoskeleton splits and the front legs emerge forward, pulling the antennae, proboscis, crumpled wings, and body out and away from the pupal case. (If humidity is too low, the emerging butterfly may get caught up in the chrysalis and emerge with crumpled wings.) The newly emerged adult climbs up the wall of the barn or other vertical surface, discharges a drop of dark fluid (exuviae), and hangs quietly while its wings expand (15 minutes) and harden (1–2 hours). Transfer the butterflies into the Butterfly Box. Place the light box on a 16/8 hour day/night schedule. Observations of adult behavior: • feeding • flying • mate seeking and mating • egg laying • daily activity relative to time • aging, dying, and death Activity: Mother Knows Best

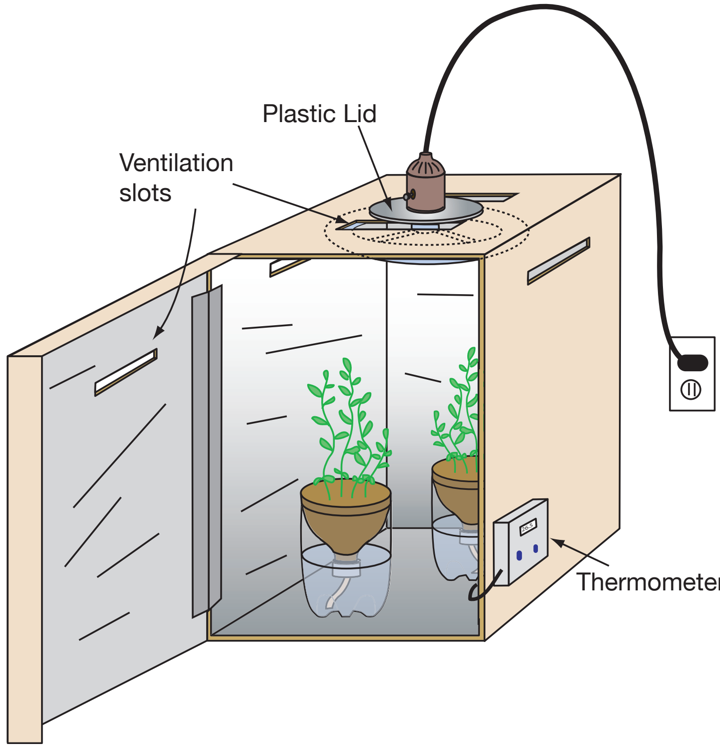


Larvae feeding in Cabbage Café.
Credit: Wisconsin Fast Plants ™

Egg laying on an ovipositron.
Credit: Wisconsin Fast Plants ™

Part 3: Constructing the Environment

A. Plant Light House/Butterfly Box

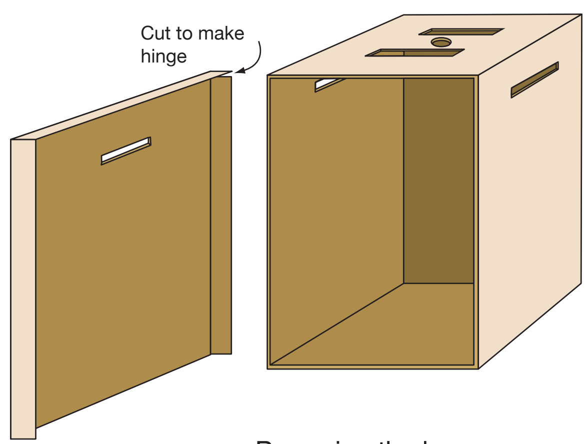


Materials:

- Copy machine paper box
- Aluminum foil
- Plastic lid (coffee can lid or food storage container lid)
- Electrical cord with socket
- Glue stick
- Duct tape or staples, brass paper fasteners, rivets, or small nuts and bolts to firmly attach the door hinge to the light house
- Scissors or knife
- Fluorescent circle light (30 to 40 watts)
- Thermometer (digital or fluid)

Construction:

1. Cut a hole in the center of the plastic lid large enough for the threaded end of the fluorescent circle light to pass through and screw into the socket.
2. Cut several 4 by 14 centimeter ventilation slots in the top and upper sides of the box and lid as shown.
3. Cut a circular hole in the center of the upper end as shown, large enough for the threads of the circular fluorescent lamp.
4. Cut off the lower flap of the box lid and cut the upper corner as shown. The long flap on one side of the lid will become the hinge for the light house door.
5. Fasten the door hinge to one side of the light house using duct tape or hardware. The door should open freely to expose the inside of the light house and remain shut when closed.
6. Apply a glue stick to the inner surfaces of the light house and the door. Fit pieces of aluminum foil to the cardboard so that all surfaces, except the ventilation slots and the light fixture hole, are covered. Use cellophane tape to reinforce the edges as needed.
7. Insert the fluorescent lightbulb from the inside of the light house up through the circular hole in the upper end of the box. Slip the plastic lid over the threads and screw on the socket cord. (The light should be on 24 hours a day when growing the nurseries.)
8. Plug the light into a wall socket.
9. Feed the lead for the digital thermometer into the box or punch a small hole at the level and slip in a fluid thermometer. The light house is ready for use raising the brassica nurseries.

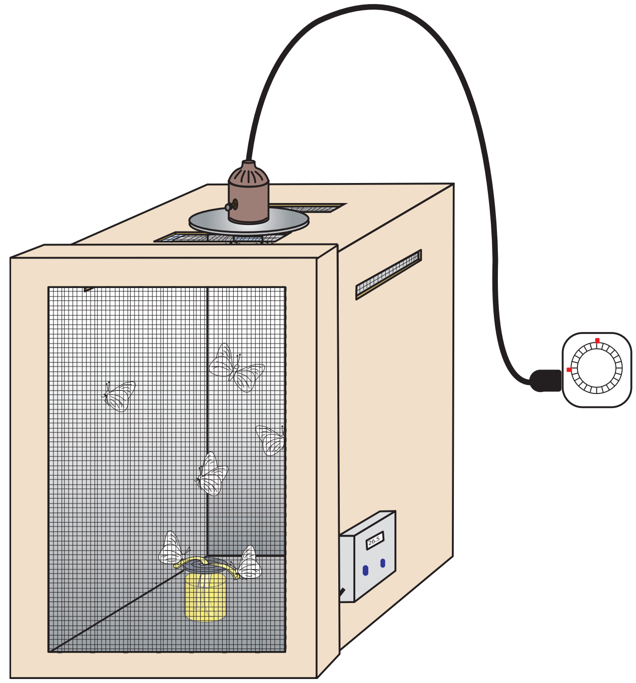


Preparing the box

Modifying the Light House to Become a Butterfly Box

Materials:
- Window screen
- Low-temperature hot glue gun and glue
- Copy machine paper box lid
- Glue stick
- Aluminum foil
- Scissors
- Electric timer switch

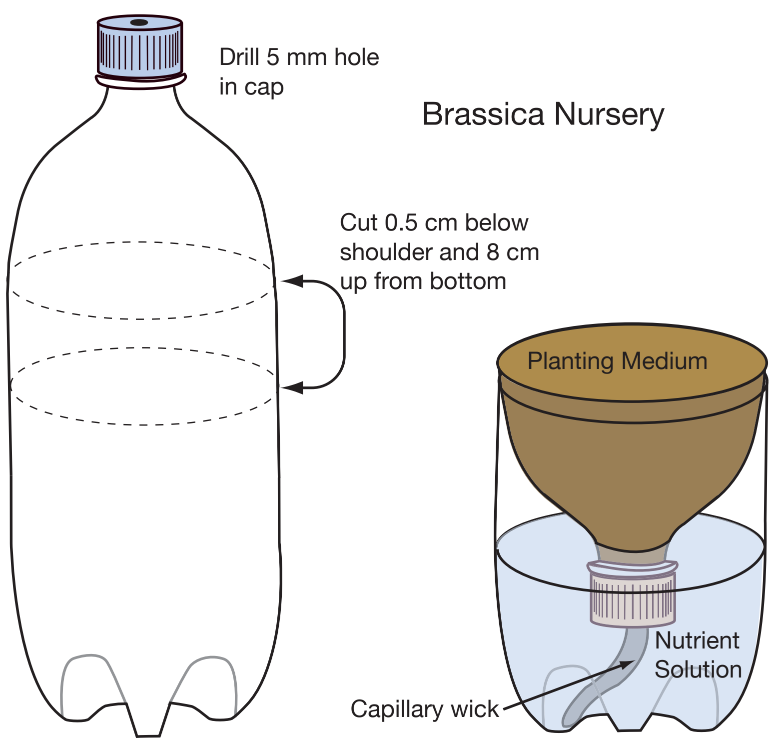
Construction:
1. Prepare the lid as you did for the light house but cut out a large window from its center.
2. Using hot glue, glue a screen over the hole.
3. Remove the door from the light house and mount this door in its place. Set the timer for 16 hours light and 8 hours dark. The butterfly box is ready for use.



B. Brassica Nursery

Materials:
- 16-, 20-, or 24-oz. soda bottles
- Unpolished cotton string (10-cm lengths) or Watermat® for capillary wicks
- Planting medium (a soilless mixture of approximately 1/2 peat moss and 1/2 vermiculite, e.g. peatlite, Scotts Redi Earth®)
- Peters 20-20-20 Professional® fertilizer with minor elements or Miracle Grow®
- Brassica Seed Mix

Construction:
1. Cut each soda bottle 0.5 cm below the rim of the shoulder to create the growing funnel, which will hold the vermiculite and planting medium. To make the bottom more stable, make a second cut in the bottom portion of the bottle to create a reservoir, 8 to 12 cm tall, for the hydroponic nutrient solution. (A single Plant Light House can accommodate eight soda bottles.)
2. Drill or melt a 5-mm hole in each bottle cap. Screw the bottle caps onto bottle tops.
3. Insert string wicks or other capillary wicking, approximately 0.5 cm x 10 cm, through the holes in the bottle caps. Check your wick before planting to be sure that it draws water well.
4. Invert the growing funnels (bottle tops) and



place in the reservoirs (bottle bases). Each wick should extend from the funnel to the floor of the reservoir.

Planting:

1. Fill the growing funnels loosely with potting mix.
2. Water from the top until water is dripping from the wick below.
3. Distribute 20–30 seeds of the Brassica Seed Mix onto the potting mix.
4. Cover the seeds with a thin layer of potting mix.
5. Fill the bottle bases (reservoirs) with nutrient solution. (Mix 1 part fertilizer with 7 parts water.)
6. Place the nurseries inside the Light House Butterfly Box with the lights on 24 hours a day. (Note: The illumination cycle changes to 16 hours light/8 hours dark when occupied by butterflies.)

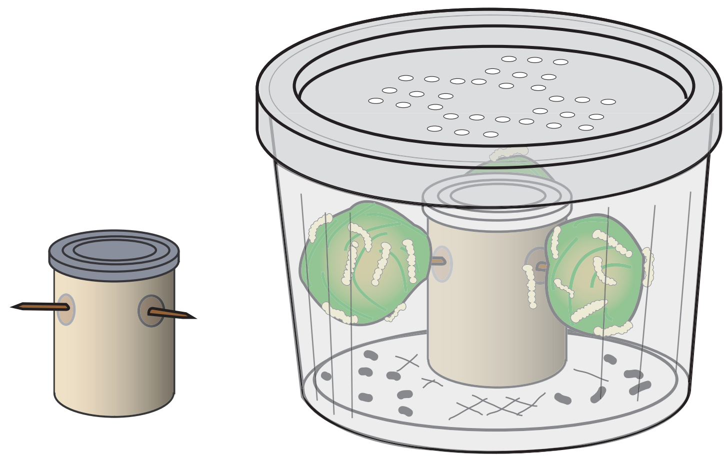
C. Brassica Barn

Materials:

- Clear plastic 1 lb. "deli" food container with lid
- Kitchen paper toweling
- One film can
- 3 upholstery tacks
- Flat toothpicks for handling larvae
- Sand (enough to fill the film can)
- Brussels sprouts or broccoli stems
- Push tacks or pins

Construction:

1. Insert 3 upholstery tacks from the inside of film can to protrude out at approximately 120 degrees apart, and about 1.5 cm from the top.
2. Fill the film can with sand. Press on the lid. This is now the Film Can Feeder.
3. Cut a kitchen paper towel "pad" to fit into the bottom of the deli container.
4. With a push tack or pin, make air holes in the deli container lid.
5. Before transferring the larvae, you need to fit the Film Can Feeder with food. Cut 2 small Brussels sprouts in half lengthwise. Remove 3–4 outer leaves. Press 1/2 of a sprout, stem end, on to each tack. Rotate sprouts so the flat surface is sloped at 45 degrees from horizontal to allow frass to fall off. Put the feeder with sprouts in the center of the paper towel pad, inside the Brassica Barn. Carefully transfer 3 or 4 *Pieris rapae* larvae, at L4–L5 stage, onto each 1/2 sprout (9-12 larvae per barn). Secure the pierced deli container lid on top. Keep the Barn out of direct sun. Classroom lighting, or a window not in direct sun, will be fine. Check your larvae daily to be sure that their current food source is fresh and clean and free of frass (larval excrement).



D. Cabbage Café (for 40–60 larvae)

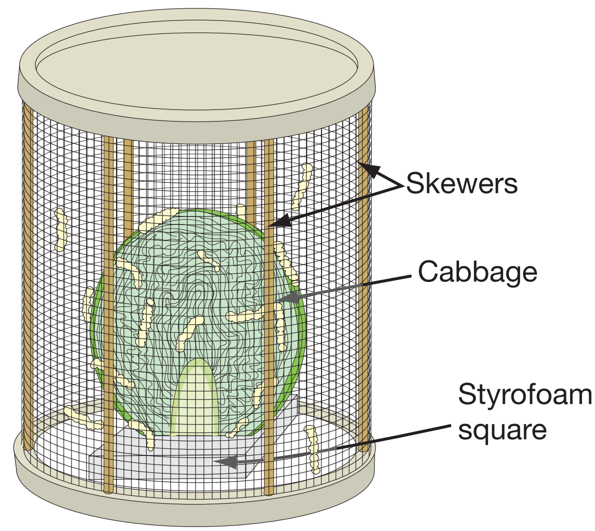
Materials:

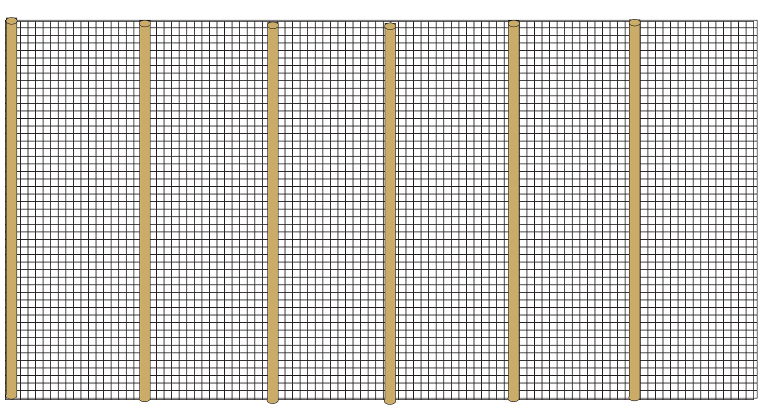
- 2 large round disposable food container lids, large ice cream containers lids, or a large petri dish with lid
- 50 cm x 20 cm piece of window screen (actual length depends on the circumference of the lids used)
- 6 bamboo skewers, cut 20 cm long
- Kitchen paper toweling
- 1/2 of one small head of green cabbage (cut cabbage lengthwise and cut some of the core end off so that the halves are able to stand upright)

• One roofing nail
• One square of Styrofoam, approximately 9 cm x 9 cm
• Low-temperature hot glue gun and glue

Construction:

1. Make several paper towel pads to fit the bottom lid. This will catch the frass and can be changed periodically.
2. Determine the length of the window screen by calculating the inside rim circumference of the lid. Cut a piece of window screen 20 cm high and the length of the circumference of the lid. Cut six skewers 20 cm long and glue them at regular intervals on the screen with hot glue. When the glue has set, join the edges of the screen to form a cylinder (skewers run parallel to the cylinder length). Make sure the cylinder fits inside the lids and then glue the edges together. Also glue the cylinder to one of the lids. This becomes the Café top.
3. Insert the roofing nail through the center of the Styrofoam square and then place the core of the cabbage onto the sharp end of the nail. Press downward to secure the 1/2 head of cabbage in a slightly forward-of-vertical position. This will allow the frass to fall off of the cabbage.
4. Place the Styrofoam with the cut cabbage attached onto the base "lid."
5. Carefully transfer up to 60 *Pieris rapae* larvae, at L3–L5 stage, onto the cabbage.
6. Place the screen and top lid over the cabbage and set the screen rim into the base "lid."
7. Keep the Café out of direct sun. Classroom lighting or a window not in direct sun will be fine.
8. The larvae will complete their development to chrysalis stage inside the Cabbage Café and will generally pupate on the sides or top of the Café.





Cleaning the Café:

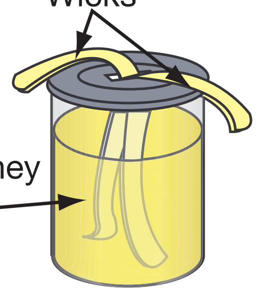
Most of the frass will fall onto the paper towel pad. The pad should be changed regularly (every day or two depending on the size of the larvae).

1. To change the pad, lift off the café top. If any larvae are on the paper towel pad, carefully remove them with toothpicksor fingers and put them back onto the cabbage.
2. Put in a clean paper towel, reposition the cabbage, and cover.

E. Film Can Sugar Feeder

Materials:
- Film canister
- 2, 0.7 x 10 cm capillary wicks, made from felt or unwaxed cotton string
- Small nail, pliers, and source of flame
- Sugar, honey, and yellow food coloring

Construction:
You will need two Sugar Feeders for each Butterfly Box in order to cycle them.
1. Hold the nail with the pliers and heat the sharp end in a flame. Melt a 1 cm x 0.3 cm slot in the lid of the film can.
2. Fill the film can with warm tap water, almost to the top. Then add 1.25 ml (1/4 teaspoon) of granulated sugar. Add 3–5 drops of honey and one drop of yellow food coloring. Shake the can to dissolve the sugar. You can mix this solution in bulk and store in the refrigerator for up to 3 weeks.
3. Soak the two capillary wicks in the yellow sugar-honey solution. Insert them through the slot in the film can lids to protrude about 3 cm. Place the lid on the can.
4. Place the Film Can Sugar Feeder in the Butterfly Box.
5. Every 2–3 days, discard any unused solution in the old Sugar Feeder. Wash all parts in warm water and soak them for 20 minutes in diluted bleach (1 part bleach to 32 parts water). Rinse the parts thoroughly and let them dry overnight.



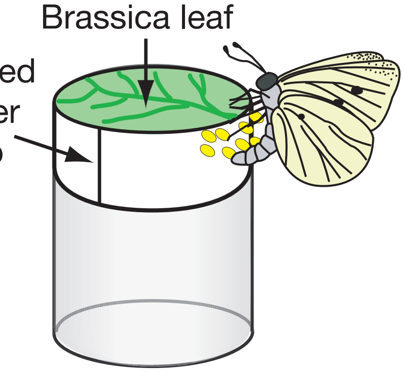
F. Ovipositron

Materials:
- Fresh brassica leaf
- Glue stick
- Film can
- Waxed paper strip, cut 1 x 4 inches

Construction:
1. Place the open end of the film can down. Apply a spot of glue with the glue stick on the side near the bottom of the film can. Attach one end of the waxed paper strip in the spot of glue and wrap the rest of the piece around the film can. Apply glue to the other end of the strip. Affix this end to the film can.

2. Glue a brassica leaf (e.g., collard green, Fast Plant, pak choi, turnip) to the bottom of the film can and trim around the rim. As the butterflies land on the rim of the Ovipositron, they deposit their eggs on the ring of waxed paper.

3. After the waxed paper strip is covered with eggs, it can be removed and transferred to a Brassica Nursery, or, you may store the eggs for 3-6 days in the refrigerator in a sealed container with a moist paper towel.



Part 4: *Pieris rapae* Activities During Rearing

"Where's Pieris?"

Begin student observations of the rearing process by having students try to locate and study the L1-L3 larvae in the Brassica Nursery. (Refer to the detailed life cycle information on pages 22 for descriptions of the larvae.) Finding Pieris is like tracking a wild animal in a forest. (Hint: Follow the feeding and the frass.)

The Salad Bar – Larval Feeding Experiment

How does a *Pieris rapae* larva "know" which food to eat? Observe the feeding preference of larvae among brassicas (cabbage/mustard) family or between brassicas and other plant families.

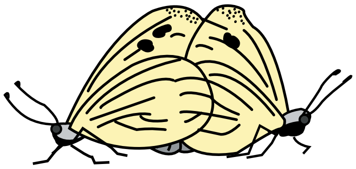
Materials per group:
- 1 Petri dish or other covered plastic container
- Kitchen paper toweling
- One or two living L4–L5 stage *Pieris rapae* larva
- Mixture of fresh leafy greens. For example, celery and carrot tops, lettuces, spinach, and some brassicas (collards, mustard or turnip greens, pak choi, Chinese cabbage, chard.)
- Flat toothpicks

Searching for larvae on brassica plants at Molina High School, Dallas, Texas.
Credit: Peggy Henson

Mating Behavior

In a Butterfly Box, mated females exhibit a very distinctive male avoidance posture that could fool you when you first see it! Can you observe and describe it? (Hint: Watch the positioning of the female abdomen.)

Outdoors in a field or garden you can often see male *Pieris rapae* chasing after a female. The female is able to avoid the males by their classic "ascending spiral flight." The male follows the female as she spirals up into the air. After a while the male tires and floats back to the ground while the female soars away seeking nectar and plants for oviposition.



Procedure:
1. Place 1–2 cm square pieces of various leafy greens on a piece of moist towel in a Petri dish.
2. Using toothpicks, gently place one or two larvae in the center of the greens and cover the container.

Observations:
- Do the larvae help you to identify the brassicas among the various vegetable leaves?

- What are the cues that determine larval feeding behavior — are they color, smell, shape, or something else?
- Could you “classify” the greens before the larvae do, either by their taste, texture, or appearance?

The Poop on Frass: “Frass Forensics”

What can we learn about plants consumed and the larvae themselves from frass? The size of the frass is directly related to the size of the larva (e.g., size of the bite and size of the gut). The size of the bite that each different instar takes is related to the size of its head (or really, its mandibles).

1. Bite Size Frass!
   Take a dried frass pellet and put it onto a glass slide in a drop of water, iodine solution, or safranin stain solution. Let it sit for 5 minutes then poke and stir it with a toothpick. The frass pellet will disperse into many small sized pieces of tissue, their size being related to the size of the mandible of the larva from which they came.

2. What Color is Your Poop?
   Feed one larvae red cabbage tissue and another white cauliflower tissue. Notice the plant tissue color as it is moving through the gut of the caterpillar. What color is the frass?

3. The Race is On!
   How quickly does food move through the gut?

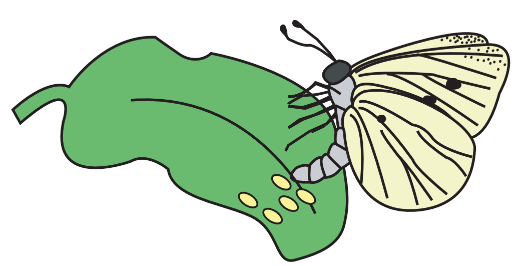
4. Botanical Anatomy via Frass!
   By suspending frass in water drops and viewing under the microscope different plant cell types are observable. Try adding IKI stain to the starch granules. (IKI is a combination of iodine and potassium iodide. IKI is a reddish-yellow solution that turns dark blue/black when put in contact with starch.) What do you observe when the stain is added?

4. Frass Fertilizer
   Consider saving the frass into a spare deli container for a Fast Plants ™ fertilizer experiment. Dry the frass in air.

How Does a Female Butterfly Know that she has Landed on a brassica?

Butterflies get much of their information about the world through chemoreceptors scattered across their bodies. In butterflies, chemoreceptors are nerve cells that open onto the surface of the exoskeleton and react to the presence of different chemicals in the environment.

Female butterflies often have important chemoreceptors on their front legs to help them find appropriate host plants for their eggs. These chemoreceptors are at the base of spines on the back of the legs, and they run up along each-spine to its tip. Females drum their legs against the plant, which releases plant juices. The chemoreceptors along the spines tell the butterfly whether she is standing on the correct plant. The Brassisca butterfly is sensing the glucosinolate chemicals in the Brassicas. Check out the Internet for more information.



Students observing the activity in a butterfly house at Molina High School, Dallas, Texas.
Credit: Peggy Henson

Mother Knows Best: Egg Laying Choices and Preferences

Do female adult butterflies prefer to lay their eggs on specific plant types?

Materials:
- Two ovipositrons
- Butterfly Box
- Two or more different leafy greens. (Brassica such as Fast Plant ™, cabbage, or collard, and other leafy greens such as lettuce, spinach, or endive)

Procedure:
Place different types of leafy greens on each ovipositron and place into a Butterfly Box with females that have mated.

Observations:
Which kind or kinds of greens do female butterflies prefer for egg laying? How do you know?

Butterflies, Brassicas, and Microgravity

Although a number of insect experiments have flown in space (house flies, bees, moths, ants, etc.) *Pieris rapae* has not yet. However, *Brassica rapa* has flown in a plant experiment on the STS-86 Mission (Colaborative Ukranian Experiment or CUE). Consequently, students are able to pioneer brassica and butterfly experiments that might someday be conducted in space. Early participants in the Brassica and Butterfly Education Project have begun a wide range of dynamic experiments to test the effects microgravity and hypergravity may have on an organism's life cycle.

Students participating in the Brassica and Butterfly Education Project have developed experiment hypotheses, designed experimental apparatus, created research protocols, conducted their experiments, and collected and analyzed their data. Creativity was the watchword in their efforts. Tools and materials employed included film cans, deli containers, soda bottles, record players, rotisserie (grill) motors, fans, rock tumblers, model rockets, and parachutes. As the students designed their experiments, they were reminded that the requirements of space flight places constraints on what can actually fly. Flight experiments need to:

- Weigh as little as possible,
- Occupy a small volume,
- Create no hazards for crew or experimental subjects, and
- Provide for basic maintenance of the experimental subjects.

For example, cleaning Butterfly Barns is relatively simple on Earth (remove the paper pad from the bottom of the barn). In microgravity, the frass will not fall to the bottom of the animal enclosure. How can this problem be addressed?

Some of the investigations conducted by the students in the Brassica and Butterfly Education Project are described below.

'Rollin on the River'

A 10th grade honors student from Lexington High School (Lexington, Massachusetts) hypothesized that butterflies in chrysalises that are in a constantly moving (rolling) state throughout metamorphosis will not emerge. The purpose of the experiment was to test the effect of a constantly changing orientation in relation to gravity on the development of a butterfly chrysalis. *Pieris rapae* chrysalises were attached to clear acetate using double stick tape. The chrysalises were placed in clear film canisters. The film canisters were placed on a track on top of a tilt table. The back and forth motion of the tilt table kept the canisters in constant motion. The rolling of the canisters changed the orientation of the enclosed chrysalis. A stationary canister was used as a control. This experiment ran for 10 days. The majority of the butterflies emerged as fully developed adults but approximately 20% of them had crumpled or bent wings.

'Crumpled Wings in Space'

Students and teachers in South Carolina, Colorado, Texas, Maine, Connecticut, and Washington began to note the frequent incidence of crumpled wings among the butterflies that had emerged from chrysalises that were in 'altered'

Pieris rapae mating.
Credit: Wisconsin Fast Plants ™

Student examining larvae in a Brassica Barn at Molina High School, Dallas, Texas.
Credit: Peggy Henson

gravity (spinning or constant motion) during metamorphosis. Students in each of these locations shared their observations with each other through the Internet. Their observations included:

- Butterflies that emerge inside moving 35-mm canisters (film cans) have stunted, curled wings.
- Butterflies that emerged while spinning and attached to the outside of canisters were not able to pump up their wings (wings flopped back and forth while spinning) and died within three days, even though they were provided with feeders. They needed to be able to hang and allow gravity help pull fluid into their wings.
- Approximately 10% of emerging butterflies (non-experimental or control) exhibited partially crumpled wings.

Could Pupae Survive Lift-off?

Students at Goldenview Middle School in Anchorage, Alaska, subjected their *Peris rapae* larvae and pupae to some of the extreme conditions that occur on space flight. A volunteer pilot at Elmendorf Air Force Base helped the students design their experiment carriers and then flew them in the cockpit of an F-15 jet during training flights. The students hypothesized that the "astropupae" would have higher than average occurrence of crumpled wings and that "astrolarvae" would exhibit signs of cuticle breach (leaking fluid). During three flights, G-forces ranged from 0 to 7 Gs and cockpit atmospheric pressures dropped to one-third sea level pressure. Some of the pupae actually flew twice (the first time as larvae). Analysis of the results led to the conclusion that there was no significant difference in wing crumpling between experimental and control groups, nor were there any problems with cuticle breach. Adult butterflies appeared to fly normally, mortality between the flight and control groups was comparable, and successive generations did not exhibit any unusual behaviors. Goldenview Middle School students concluded that *Pieris rapae* would be a suitable organism for space flight experiments. In the finest NASA tradition, students named their experiment PEEG-LEEG (Pupa Experiencing Extreme G force – Larva Experiencing Extreme G force).

"Oopsy Daisy" Project: Will butterflies be able to lay eggs in microgravity?
Missouri students bolted Ovipositrons in different orientations to see if butterflies will lay eggs upside down. They reported that almost all eggs are deposited on the lower side of the Ovipositrons. Students plan to extend their study to investigate the effect of light and warmth on egg laying positions because the butterflies tend to congregate around the lights. The location of lights in an actual microgravity enclosure might assist butterflies in egg laying.

Spinning a Life Cycle: Will butterflies that spend their entire life cycle in motion be able to fly "straight?"
Arizona students raised butterflies from egg through pupa on a record turntable spinning at a constant rate of 17 RPM. Students observed that butterflies raised in this manner were able to fly straight and there were no apparent differences between the experimental and control groups. Future studies will increase the rate to 33 RPM.

Pieris rapae crysalisses
Credit: Wisconsin Fast Plants ™

Appendix A. Detailed Life Cycle Stages and Timeline for *Pieris rapae*

Stages and Approximate Timeline (Temperature ~23^{0}C)

EGG

DAY	STAGE	NOTES
<1	E1	Creamy white, within 24 hrs
<1	E2	White, sometimes with orange tint
3	E3	Pink-purple, mandibles and eye spots visible
	E4	Larval movement within egg
	E5	Larva chewing shell and emergence

LARVA

DAY	STAGE	NOTES
4	L1-1	Emergent larva, beginning to feed and ambulate, head diameter 0.32 mm, greater than body diameter
5	L1-2	Larva feeds, body elongates and swells
	L1-3	Larva quiescent, preparing to molt
6	L1-4	Larva molting
	L2-1	Larva ingests cuticle (not L-1 head capsule), head diameter 0.58 mm, large compared to body
7	L2-2	Larva feeds, body elongates and swells
	L2-3	Larva quiescent on silk rug, preparing to molt
8	L2-4	Larva molting
	L3-1	Larva ingests cuticle (not L-2 head capsule)
9	L3-2	Larva feeds, body elongates and swells, testes visible on males
	L3-3	Larva quiescent on silk mat, preparing to molt
10	L3-4	Larva molting
	L4-1	Larva ingests cuticle (not L-3 head capsule)
11–12	L4-2	Larva feeds, body elongates and swells, larva move actively
13	L4-3	Larva quiescent on silk rug, preparing to molt, body diameter large compared to head diameter
	L4-4	Larva molting

13	L5-1	Larva ingests cuticle (not L-4 head capsule) head capsule diameter 1.98+/-mm, head large compared to body diameter
14–16	L5-2	Larva feeds voraciously, body swells and elongates, larva moves actively to fresh food sources, copious frass is produced, testes visible on males
17	L5-3	Larva ceases feeding, actively seeks a suitable site for final molt and pupation, final frass pellet in hind gut is visible and salmon pink
18	L5-4	At pupation site larva lays down a substantial silk mat to surface, attaches proleg crochettes and forelegs to the mat and releases final pink frass pellet, and weaves a multistranded silk belt over the midbody attached to the silk mat on either side of the body. Larva appears quiescent prior to molting
	L5-5	Molting, the L-5 cuticle splits from the head first. With active undulation and extreme contraction of the cuticle, the head capsule and cuticle retract posteriorly under the silk belt drawing trachea from the spiracles (air pores) in the sides, which appear as white bands. With active undulations the L-5 cuticle with head capsule slips from the new pupal cuticle beneath the silk belt and contracts to approximately 2x2x3mm and is cast off. A relatively active series of twisting undulations of the flexible pupa results in the attachment of a new set of posterior crochettes (cremaster) to a tuft of silk loops in the posterior portion of the silk mat. The pupa is firmly attached to the silk mat by the cremaster and the silk band.

PUPA

18	Pg-1	(Pg - pupa green) Pupal cuticle is soft and pale green to dark with characteristic ridges on dorsal side; cuticle begins to harden
19–23	Pg-2	Pupal cuticle becomes hardened, assumes characteristic shape, and reveals on clear cuticle the outline of where wings, legs, antennae, and eyes will develop; color may be clear pale green to darkly speckled with melanized pigment; dorsal ridges are light tan to dark.
24	Py-1	First appearances of faint cream to light pigmentation of wing outline
25	Py-2	Wing coloring more distinctly cream to light yellow
26	Py-3	Wings cream to yellow with distinct darkened veins
27	Ps-1	Appearance of one or two faint dark spots in center of wing outline
28	Ps-2	Intensification of darkening of wing spots, dark wing tip appears
29	Ps-3	Wing spots and tip black, darkening of head and thorax visible, emergence in <1 day
29–30	Ps-4	Wing spots dark, hairy scales on head thorax and abdomen visible, emergence imminent (< 6 hours)
	Ps-5	Emergence, cuticle splits, forelegs emerge and rapidly pull adult out of pupal case. Adult crawls upward, wings expand in a few minutes, brown exuvial fluid is released, and wings harden in an hour or two.

ADULT

31	A-1	Adult remains relatively quiet for a day, neither feeding nor flying
32	A-2	Adult begins to fly, forage for nectar and seeks mate
32–33	A-3	Mating; females have 2 forewing spots, males have 1 forewing spot; copulation is tail to tail and may persist for several hours.
33–	A-4	Egg laying; females lay up to 300 eggs over a 7–14 day period, peak activity appears to be around midday
30–50	A-5	Adults die between 1–20 days after emergence

Appendix B. Microgravity Experiments Microgravity Experiments with *Pieris rapae*: Question and Idea Bank

One of the key pieces of the Brassica and Butterfly Education Project is sharing. The following list compiles some of the ideas, questions, and tips that students and teachers across the country have shared with each other. This list could be the starting point for exciting new experiments with brassicas and butterflies.

Ideas for altering gravity:
- Turntable
- Rotisserie
- Potter's wheel
- Rock tumbler
- Dropping
- Clinostat

Things to be considered:
- Design of the experiment
- Equipment to be used as experimental chamber
- Film cans
- Soda bottles
- Other containers
- Stage(s) of life cycle for experimenting
- How to secure the organism during spinning
- Duration of experiment
- Monitoring experiment and gathering data

Eggs, in microgravity
- Will eggs hatch?
- Is the percentage of hatching the same as in Earth gravity?
- Are there other environmental factors that might be affecting hatching and/or rate of hatching?
- Are they able to locate the food source?
- How soon do they begin to eat?

Larvae, in microgravity:
- What larval stage would you choose to work with?
- How long should they spin?
- Do they eat at the same rate?
- Is the rate of growth altered?
- Are they able to molt?
- Is their ambulation pattern the same as in Earth gravity?
- Are they able to pupate?
- Do they pupate at the same rate as in Earth gravity?
- Is there any pattern to the direction in which they pupate?
- Is there any difference in the pupae that form?
- Is the size of the pupae the same?
- How securely are the pupae attached?

Pupae, in microgravity:
- How long should they spin?
- Is the rate of metamorphosis affected?
- Is the ability to emerge affected in any way?
- Can they emerge successfully in a small space (e.g., film canister)?
- Should spinning stop before or after they emerge?
- Is the percentage of successful emergence the same as in Earth gravity?
- Is the physiology of the emerging butterfly affected?
- Are they able to pump up their wings normally?

Students perform a free fall test at Molina High School, Dallas, Texas.
Credit: Peggy Henson

Butterfly, in microgravity:

- Can they fly normally?
- Can/do they mate?
- Can they eat?
- Do they eat as much/as often as in Earth gravity?
- Can they lay eggs?
- Is the rate of egg laying affected?
- Is the percentage of viable eggs the same?
- Can they lay eggs upside down? (How would you design the experiment to examine that question?)

Other potential environmental factors:

- During microgravity experimenting what other environmental factors may confound the results of the experiment?
- Light vs. darkness
- Temperature
- Humidity
- How can you address the effect of the environment in the design of your experiment? Do you need to?

Stages of the life cycle (eggs, larvae, pupae, butterfly):

- Is one stage more responsive (vulnerable) to microgravity than another?
- How could you experiment with more than one stage of the life cycle? Why would you want to?

Glossary

Ambulation: to walk from place to place; move about; crawl.

Brassica: any of various plants of the genus brassica of the mustard family, including cabbage, broccoli, and turnip.

Brassica butterfly: also known as white cabbage butterfly. Physical characteristics: white, with one (male) or two (female) rounded black spots on dorsal forewing.

Camouflage: concealment by protective coloring.

Chrysalis: a pupa, especially of a moth or butterfly, enclosed in a firm case or cocoon.

Chemoreceptor: a sensory nerve cell or sense organ, as of smell or taste, that responds to chemical stimuli.

Clinostat: a device for investigating gravitropism in plants by continually rotating them through different angles.

Cold-blooded: having a body temperature that fluctuates, approximating that of the surrounding air, land, or water.

Cremaster: the apex of the last abdominal segment of an insect; velcro-like hooks.

Crochette: Curved spines or hooks on the prolegs of caterpillars and on the cremaster of the pupae.

Cuticle: the noncellular, hardened or membranous protective covering of many invertebrates, such as the transparent membrane that covers annelids.

Drop tower: a long vertical shaft used for dropping experiment packages, enabling them to achieve microgravity conditions through free fall.

Embryogenesis: the development and growth of an embryo.

Environmental variables: anything changeable; esp., a quality or quantity that varies or may vary.

Exoskeleton: a hard outer structure, such as the shell of an insect or crustacean, that provides protection or support for an organism.

Frass: larval excrement.

Germination: the process of sprouting from a seed or a bud.

Glucosinolate chemicals: a class of sulfur- and nitrogen-containing secondary metabolites found mainly in members of the Family *Brassicaceae*. Although the function of glucosinolates themselves is not well known, their breakdown products seems to play a role in plant defenses against herbivores and pathogens. Glucosinolate breakdown products have been linked to reduced cancer risks in laboratory animals.

Gravity: The attractive force between two objects that is proportional to their masses; generally it is taken to be the acceleration of an object to the Earth.

Hatching: to emerge from or break out of an egg.

Larva: the newly hatched, earliest stage of any of various animals that undergo metamorphosis, differing markedly in form and appearance from the adult.

Life cycle: a progression through a series of differing stages of growth and development.

Metamorphosis: a change in the form and often habits of an animal during normal development after the embryonic stage. Metamorphosis can include, in insects, the transformation of a maggot into an adult fly and a caterpillar into a butterfly.

Microgravity: an environment in which the apparent weight of a system is small compared to its actual weight due to gravity. The mass of an object will remain constant.

Molting: to shed periodically part or all of a coat or an outer covering, such as feathers, cuticle, or skin, which is then replaced by a new growth.

Organism: an individual form of life, such as a plant, animal, bacterium, protist, or fungus; a body made up of organs, organelles, or other parts that work together to carry on the various processes of life.

Ovipositron: an object on which eggs are deposited.

Pathogen: an agent that causes disease, especially a living microorganism such as a bacterium or fungus.

***Pieris rapae*:** scientific name for the brassica butterfly.

Pigment: a substance, such as chlorophyll or melanin, that produces a characteristic color in plant or animal tissue.

Proboscis: the slender, tubular feeding and sucking organ of certain invertebrates, such as some insects, worms, and mollusks.

Pupa: an insect in the inactive stage of development (when it is not feeding) intermediate between larva and adult.

Pupation: to go through a pupal stage.

Spiracle: a respiratory aperture; especially any of several tracheal openings in the exoskeleton of an insect or a spider.

Trachea: one of the internal respiratory tubes of insects and some other terrestrial arthropods.

Undulation: a regular rising and falling or movement to alternating sides.

Publications

The following publications are available for downloads at the address below:

http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/.index.html

Wireless Drop Tower for Microgravity Demonstrations:
EB-2003-01-19-MSFC

Microgravity - A Teacher's Guide with Activities in Science, Mathematics, and Technology: EG-1997-08-110-HQ

Microgravity Demonstrator: EG-1998-12-49-MSFC

NASA Student Glovebox - An Inquiry-Based Technology Educator's Guide: EG-2000-09-004-GRC

Teachers and Students Investigating Plants in Space
A Teacher's Guide with Activities for Life Sciences:
EG-1997-02-113-HQ

NASA Student Involvement Program-Flight Opportunities
Educator's Resource Guide: EP-2002-08-393-HQ

Microgravity - Liftoff to Learning Series, A Videotape for Physical Science: EV-1997-07-008-HQ

Plants In Space - Liftoff to Learning Series, A Videotape for Biology and Life Science: EV-1998-12-017-HQ

Butterflies and Brassica Sources

Wisconsin Fast Plants™ Program
University of Wisconsin Madison
Science House
1630 Linden Drive
Madison, WI 53706
1-800-462-7417 or 1-608-263-2634
wfp@fastplants.org
www.fastplants.org

Butterfly eggs and Brassica Seed Mix are available through Carolina Biological Supply Company
(1-800-334-5551)
www.carolina.com

NASA Resources for Educators

Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in multimedia format. Educators can obtain a catalogue and an order form by one of the following methods:

CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074-9799
Phone: (440) 775-1400
FAX: (440) 775-1460
E-mail nasaco@leeca.org
Home Page: www.nasa.gov/education/core

Educator Resource Center Network (ERCN)

To make additional information available to the education community, NASA has created the NASA Educator Resource Center (ERC) network. Educators may preview, copy, or receive NASA materials at these sites. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, Northern CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Educator Resource Center
NASA Ames Research Center
Mail Stop 253-2
Moffett Field, CA 94035-1000
Phone: (650) 604-3574
http://amesnews.arc.nasa.gov/erc/erchome.html

IL, IN, MI, MN, OH, WI
NASA Educator Resource Center
NASA Glenn Research Center
Mail Stop 8-1
21000 Brookpark Road
Cleveland, OH 44135
Phone: (216) 433-2017
http://www.grc.nasa.gov/WWW/PAO/html/edteachr.htm

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Educator Resource Laboratory
NASA Goddard Space Flight Center
Mail Code 130.3
Greenbelt, MD 20771-0001
Phone: (301) 286-8570
http://www.gsfc.nasa.gov/vc/erc.htm

CO, KS, NE, NM, ND, OK, SD, TX
Space Center Houston
NASA Educator Resource Center for
NASA Johnson Space Center
1601 NASA Road One
Houston, TX 77058
Phone: (281) 244-2129
http://www.spacecenter.org/educator_resource.html

FL, GA, PR, VI
NASA Educator Resource Center
NASA Kennedy Space Center
Mail Code ERC
Kennedy Space Center, FL 32899
Phone: (321) 867-4090
http://www-pao.ksc.nasa.gov/kscpao/educate/edu.htm

KY, NC, SC, VA, WV
Virginia Air & Space Center
NASA Educator Resource Center for
NASA Langley Research Center
600 Settlers Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 x 757
http://www.vasc.org/erc/

AL, AR, IA, LA, MO, TN
U.S. Space and Rocket Center
NASA Educator Resource Center for
NASA Marshall Space Flight Center
One Tranquility Base
Huntsville, AL 35807
Phone: (256) 544-5812
http://erc.msfc.nasa.gov

MS
NASA Educator Resource Center
NASA Stennis Space Center
Mail Stop 1200
Stennis Space Center, MS 39529-6000
Phone: (228) 688-3338
http://education.ssc.nasa.gov/erc/erc.htm

CA
NASA Educator Resource Center for
NASA Jet Propulsion Laboratory
Village at Indian Hill
1460 East Holt Avenue, Suite 20
Pomona, CA 91767
Phone: (909) 397-4420
http://education.jpl.nasa.gov/resources/

AZ and Southern CA
NASA Educator Resource Center
NASA Dryden Flight Research Center
PO Box 273 M/S 4839
Edwards, CA 93523-0273
Phone: (661) 246-2445
Toll Free: 800-521-3416 x2445
http://www.dfrc.nasa.gov/Education/ERC/

VA and MD's Eastern Shores
NASA Educator Resource Center for
GSFC/Wallops Flight Facility
Visitor Center Building J-17
Wallops Island, VA 23337
Phone: (757) 824-2298
http://www.wff.nasa.gov/~WVC/ERC.htm

Regional Educator Resource Centers offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as regional ERCs in many states. A complete list of regional ERCs is available through CORE, or electronically via NASA Spacelink at www.nasa.gov/education/ercn

The NASA Portal

The NASA Portal serves as the gateway for information regarding content, programs, and services offered by NASA for the general public and, specifically, for the educational community with the goals to inform, involve, and inspire. NASA's goal is to improve interactions for students, educators, and families with NASA and its education resources. Visit the NASA Portal and begin a journey of personal discovery. http://www.nasa.gov

NASA's Education Home Page serves as the education portal for information regarding educational programs and services offered by NASA for the American education community. This high-level directory of information provides specific details and points of contact for all of NASA's educational efforts, Field Center offices, and points of presence within each state. Visit this resource at the following address: http://education.nasa.gov.

NASA Spacelink is one of NASA's electronic resources specifically developed for the educational community. Spacelink serves as an electronic library to NASA's educational and scientific resources, with hundreds of subject areas arranged in a manner familiar to educators. Using Spacelink Search, educators and students can easily find information among NASA's thousands of Internet resources. Special events, missions, and intriguing NASA Web sites are featured in Spacelink's "Hot Topics" and "Cool Picks" areas. Spacelink may be accessed at: http://spacelink.nasa.gov.

NASA Spacelink is the official home to electronic versions of NASA's Educational Products. A complete listing of NASA Educational Products can be found at the following address: http://spacelink.nasa.gov/products.

NASA Television (NTV) features Space Station and Shuttle mission coverage, live special events, interactive educational live shows, electronic field trips, aviation and space news, and historical NASA footage. Programming has a 3-hour block—Video (News) File, NASA Gallery, and Education File—beginning at noon Eastern and repeated four more times throughout the day. Live feeds preempt regularly scheduled programming.

Check the Internet for programs listings at: http://www.nasa.gov/multimedia/nasatv/

For more information on NTV, contact:
NASA TV
NASA Headquarters - Code P-2
Washington, DC 20546-0001
Phone (202) 358-3572

NTV Weekday Programming Schedules (Eastern Times)

NASA Gallery / History Hour	Education File	Video File
7–8 a.m.	8–9 a.m.	9–10 a.m.
10–11 a.m.	2–3 p.m.	12–1 p.m.
1–2 p.m.	5–6 p.m.	3–4 p.m.
4–5 p.m.	8–9 p.m.	6–7 p.m.
7–8 p.m.	11–12 p.m.	9–10 p.m.
10–11 p.m.	2–3 a.m.	12–1 am.
1–2 a.m.		

Live feeds preempt regularly scheduled programming.

How to Access Information on NASA's Education Program, Materials, and Services (EP-2002-07-345-HQ) This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network, or electronically via NASA Spacelink.
http://spacelik.nasa.gov/products/Acessing.NASA.Education.Brochure/

Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educator_guide. Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank You.

Butterflies and Brassica - Educator's Guide

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To achieve America's goals in Educational Excellence, it is NASA's mission to develop supplementary instructional materials and curricula in science, mathematics, and technology. NASA seeks to involve the educational community in the development and improvement of these materials. Your evaluation and suggestions are vital to continually improving NASA educational materials.

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   ☐ NASA Educator Resource Center
   ☐ NASA Central Operation of Resources for Educators (CORE)
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